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"Comparison Of Bolton Ratio In Normal Occlusion And Different Malocclusion Groups In Navi Mumbai Population – An Analytical-Study

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Abstract
Introduction: *Malocclusion, a misalignment of teeth and jaws, is one of the most common orthodontic problems and can result in functional issues such as difficulty in chewing, speech impediments, and increased susceptibility to periodontal disease. Understanding the underlying causes of malocclusion, including tooth size discrepancies as measured by Bolton's ratios, is essential for developing effective treatment strategies tailored to specific populations. By establishing normative Bolton ratios for the Navi Mumbai population, the study will contribute valuable data that can be used to enhance the precision and effectiveness of orthodontic diagnosis and treatment planning.*
Objective: *The study aimed to compare the Bolton ratio in normal occlusion and different malocclusion groups within the Navi Mumbai population to determine the applicability of Bolton's analysis in this demographic.*
Materials and Methods: *An analytical cross-sectional study was conducted at the Department of Orthodontics. The study included 240 participants aged between 15 and 30 years, divided equally across four groups: Class I, Class II Division 1, Class II Division 2, and Class III malocclusions. Mesiodistal tooth dimensions were measured using digital vernier calipers, and Bolton's anterior and overall ratios were calculated. Statistical analysis was performed using SPSS software version 2.0, with significance set at $p < 0.05$.*
Results: *The gender distribution was equal across all groups with no significant differences ($p = 1.000$). Age distribution also showed no significant differences ($p = 0.7$). Anterior ratios were consistent across malocclusion groups with no significant differences ($p = 0.466$). However, the overall Bolton ratio showed a statistically significant difference between Class II Division 1 and Class III malocclusions ($p = 0.049$).*
Conclusion: *The study found that while anterior Bolton ratios remained consistent across malocclusion groups, overall ratios varied significantly, particularly between Class II Division 1 and Class III malocclusions. These findings suggest the need for population-specific Bolton ratios for more accurate orthodontic diagnosis and treatment planning in the Navi Mumbai population.*
Keywords: *Bolton ratio, malocclusion, tooth size discrepancy, orthodontics, Navi Mumbai population.*

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I. Introduction

The accurate alignment of teeth within the dental arch is critical for achieving optimal function and aesthetics in orthodontics. One of the key factors in achieving this alignment is the proportional relationship between the sizes of the upper and lower teeth, commonly evaluated through Bolton's analysis. Bolton's ratios, introduced by Wayne A. Bolton in 1958, have become a standard tool in orthodontic diagnosis and treatment planning, providing clinicians with the means to identify discrepancies in tooth size that could lead to malocclusion if not properly addressed [1]. The Bolton anterior and overall ratios quantify the proportionality between the mesiodistal widths of the maxillary and mandibular teeth, offering a benchmark against which individual cases can be compared [2].

Malocclusion, a misalignment of teeth and jaws, is one of the most common orthodontic problems and can result in functional issues such as difficulty in chewing, speech impediments, and increased susceptibility to

periodontal disease [3]. The prevalence of malocclusion varies significantly across different populations, influenced by genetic, environmental, and cultural factors [4]. In India, malocclusion rates have been reported to be high, with studies indicating that up to 40% of the population may be affected [5]. Understanding the underlying causes of malocclusion, including tooth size discrepancies as measured by Bolton's ratios, is essential for developing effective treatment strategies tailored to specific populations.

Numerous studies have explored the application of Bolton's ratios in different populations, revealing significant variations that suggest the need for population-specific data. For instance, research conducted in various ethnic groups has shown that Bolton's original ratios, derived from a predominantly Caucasian sample, may not be universally applicable [6]. In a study of Nigerian orthodontic patients, for example, significant deviations from Bolton's ratios were observed, highlighting the importance of considering ethnic and population-specific differences in tooth size [7]. Similarly, research conducted in Chinese populations has demonstrated the need for adjusted Bolton ratios to account for the distinct dental characteristics observed in this group [8].

The Navi Mumbai population represents a unique demographic with its own genetic and cultural influences on dental characteristics. However, there is limited research specifically examining Bolton ratios and tooth size discrepancies in this population. The few studies that have been conducted in India have primarily focused on broader regions or specific subpopulations, often without considering the diverse ethnic backgrounds that characterize the Navi Mumbai region [9]. This gap in the literature underscores the need for targeted research to establish accurate Bolton ratios for this population, which could improve the precision of orthodontic diagnosis and treatment planning.

Bolton's analysis is particularly valuable in cases where patients present with malocclusions that are not easily explained by traditional diagnostic criteria. In such cases, a discrepancy between the size of the upper and lower teeth may be the underlying cause, and failure to address this issue can lead to suboptimal treatment outcomes [10]. For example, a patient with a Class III malocclusion may have a perfectly normal skeletal relationship but still exhibit significant occlusal issues due to a disproportionate tooth size. In these cases, accurate measurement and comparison using Bolton's ratios can guide clinicians in making necessary adjustments, such as selective tooth reshaping or extraction, to achieve proper alignment [11].

Despite the widespread use of Bolton's ratios in clinical practice, their application in non-Western populations has been met with mixed results. Studies in populations from Asia, Africa, and the Middle East have reported significant deviations from Bolton's original ratios, suggesting that these benchmarks may not be universally applicable [12]. This has led to calls for the development of population-specific Bolton ratios that take into account the unique dental characteristics of different ethnic groups [13]. In India, where genetic diversity is immense, this issue is particularly relevant. Studies conducted in various regions of India have shown that tooth size discrepancies can vary significantly even within the same country, further emphasizing the need for localized research [14].

Moreover, the implications of tooth size discrepancies extend beyond mere aesthetics. Research has shown that mismatches in tooth size can lead to long-term functional issues, including abnormal wear patterns, temporomandibular joint disorders, and increased risk of periodontal disease [15]. This makes it imperative for orthodontists to accurately assess and address these discrepancies during treatment planning. By establishing population-specific Bolton ratios for the Navi Mumbai population, orthodontists can improve their diagnostic accuracy and provide more effective, personalized care for their patients [16]. The study of Bolton ratios in the Navi Mumbai population is both timely and necessary. As orthodontic treatment becomes more widely sought after in India, the need for accurate, population-specific diagnostic tools will only increase. This research not only addresses a critical gap in the literature but also has the potential to significantly improve the quality of orthodontic care provided to patients in this region. By establishing normative Bolton ratios for the Navi Mumbai population, the study will contribute valuable data that can be used to enhance the precision and effectiveness of orthodontic diagnosis and treatment planning

II. Methodology

1. Study Design

This study was designed as an analytical cross-sectional study aimed at comparing the Bolton ratio in normal occlusion and different malocclusion groups within the Navi Mumbai population.

2. Study Setting

The study was conducted in the Dept of Orthodontics.

3. Study Duration

The study was carried out over a period from 2021 to 2024.

4. Participants - Inclusion and Exclusion Criteria

Inclusion Criteria:

Indian nationals aged between 15 and 30 years.
Participants with fully erupted permanent teeth from the right first molar to the left first molar.
Patients presenting with bilateral Angle's molar relation.

Exclusion Criteria:

Patients with multiple missing teeth.
Participants with unerupted permanent teeth.
Teeth that were unrestored and carious or had full coverage restoration.
Teeth with proximal wear/attrition or congenital defects.

5. Study Sampling

Participants were selected from the pre-treatment records of patients attending the Department of Orthodontics. The selection followed a systematic random sampling technique to ensure equal representation of each malocclusion group.

6. Study Sample Size

The calculated sample size for the study was 240 patients, equally distributed across the different malocclusion groups: Class I, Class II Division 1, Class II Division 2, and Class III. Each group consisted of an equal number of males and females.

7. Study Groups

The study population was divided into four groups based on the type of malocclusion:

- Group A: Class I
- Group B: Class II Division 1
- Group C: Class II Division 2
- Group D: Class III

8. Study Parameters

The study parameters included the Anterior Bolton Index (ABI) and the Overall Bolton Index (OBI), which were calculated to evaluate the tooth size discrepancies between the maxillary and mandibular teeth.

9. Study Procedure

Pre-treatment dental casts of the selected participants were used for measurement. The mesiodistal diameters of the teeth were measured using a digital vernier caliper with an accuracy of 0.01 mm. Measurements were taken at the widest part of each tooth from the buccal (labial) aspect and were held occlusally parallel to the long axis of the tooth. The Bolton ratios were then calculated using the collected data.

10. Study Data Collection

Data collection involved measuring the mesiodistal diameters of each tooth on the pre-treatment casts. The measurements were recorded from the first molar to the first molar and subjected to Bolton's analysis. The Anterior Bolton Index (ABI) and Overall Bolton Index (OBI) were calculated using the following formulas:

- ABI: (Sum of mandibular 6 / Sum of maxillary 6) × 100
- OBI: (Sum of mandibular 12 / Sum of maxillary 12) × 100

11. Data Analysis

The collected data were compiled and analyzed using SPSS software version 2.0. Descriptive statistics were expressed as mean and standard deviations for each group. The intra-class correlation coefficient test was performed to determine the reproducibility of the measures. Inter-group and intra-group comparisons were done using the Chi-square test, One-way ANOVA F test, and Tukey's post-hoc test. A p-value of less than or equal to 0.05 was considered statistically significant.

12. Ethical Considerations

The study was conducted following ethical guidelines and principles. The study was approved by the ethical review board ensuring that participants' confidentiality and rights were upheld throughout the research.

III. Results

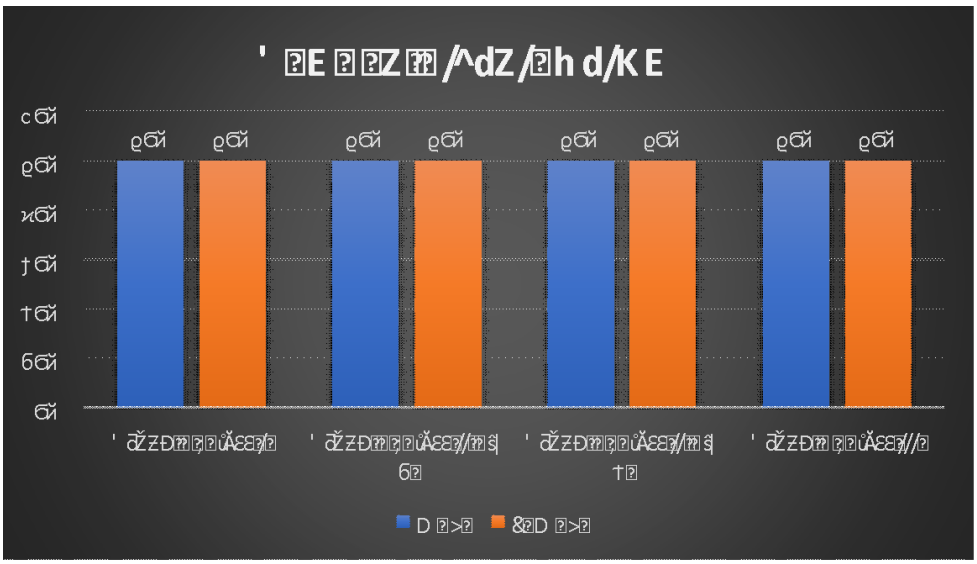
Gender distribution in each malocclusion group

The gender distribution across the four malocclusion groups (Class I, Class II Division 1, Class II Division 2, and Class III) shows an equal representation of males and females, with each group consisting of 30 males (50%) and 30 females (50%). The Chi-square test value is 0.0, and the p-value is 1.000, indicating that there is no statistically significant difference in gender distribution across the different malocclusion groups.

Table 1: Gender distribution in each malocclusion group

	Mean	SD
Group A (Class I)	30(50%)	30 (50%)
Group B (Class II Division 1)	30 (50%)	30 (50%)
Group C (Class II Division 2	30(50%)	30 (50%)
Group D (Class III)	30 (50%)	30 (50%)
Chi square test value = 0.0, p =1.000 (no statistical significant difference)		

p>0.05 – No statistical significant difference



Graph 1: Gender distribution in each malocclusion group

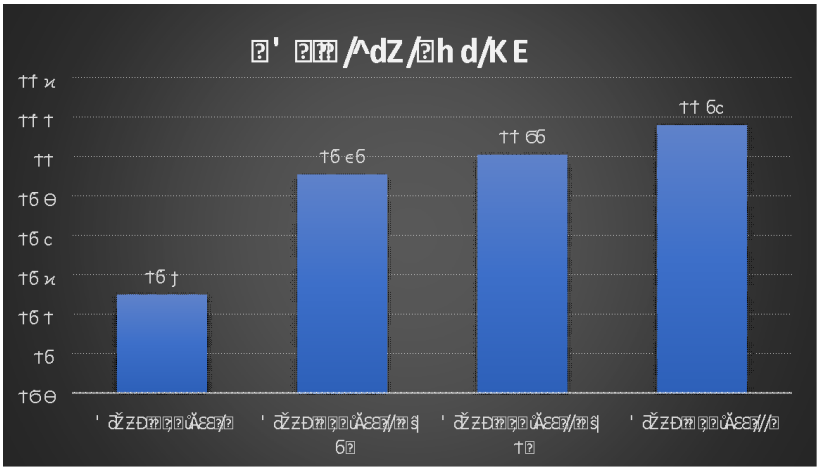
Age Distribution in Each Malocclusion Group

The age distribution among the four malocclusion groups reveals that the mean ages for Groups A, B, C, and D are relatively similar, with minor variations. The mean age ranges from 21.3 to 22.16 years across the groups. The One-way ANOVA F test value is 0.475 with a p-value of 0.7, suggesting that there is no statistically significant difference in age distribution between the groups.

Table 2: Age distribution in each malocclusion group

	Mean	SD
Group A (Class I)	21.3	4.33
Group B (Class II Division 1)	21.91	4.31
Group C (Class II Division 2	22.01	4.22
Group D (Class III)	22.16	4.23
One way Anova F test value = 0.475, p = (no statistical significant difference)		0.7

p>0.05 – No statistical significant difference



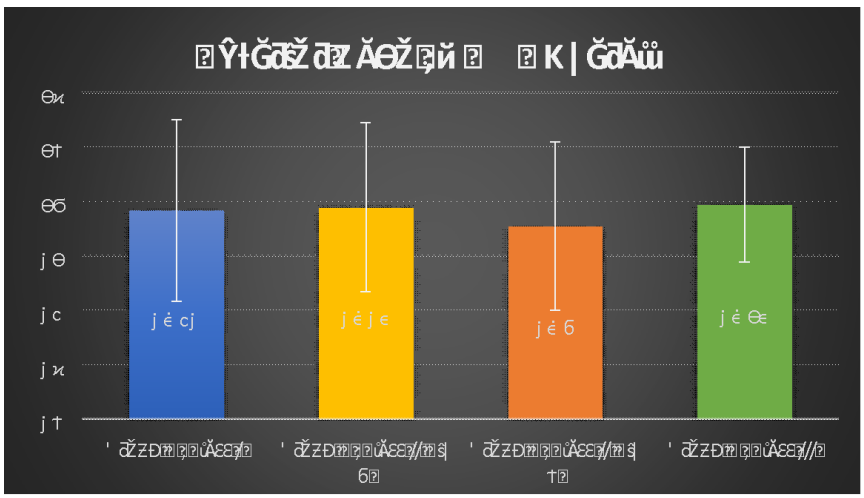
Graph 2: Age distribution in each malocclusion group

Comparison of Anterior Ratio (%) Between Four Malocclusion Groups

The anterior ratio comparison across the four malocclusion groups shows that the mean anterior ratio percentages are fairly consistent, ranging from 79.1% to 79.89%. The One-way ANOVA F test yields a value of 0.854 with a p-value of 0.466, indicating no statistically significant difference in anterior ratios between the different malocclusion groups.

Table 3: Comparison of Anterior ratio (%) between four malocclusion groups using One way Anova F test

Anterior ratio (%)	Mean	SD	One-way Anova F test	P value, Significance
Group A (Class I)	79.67	3.33		
Group B (Class II Division 1)	79.79	3.11		
			F = 0.854	p =0.466
Group C (Class II Division 2	79.1	3.09		
Group D (Class III)	79.89	2.12		



Graph 3: Comparison of Anterior ratio (%) between four malocclusion groups using one way Anova F test

Pairwise Comparison Between Different Malocclusion Groups in Relation to Anterior Ratio (%)

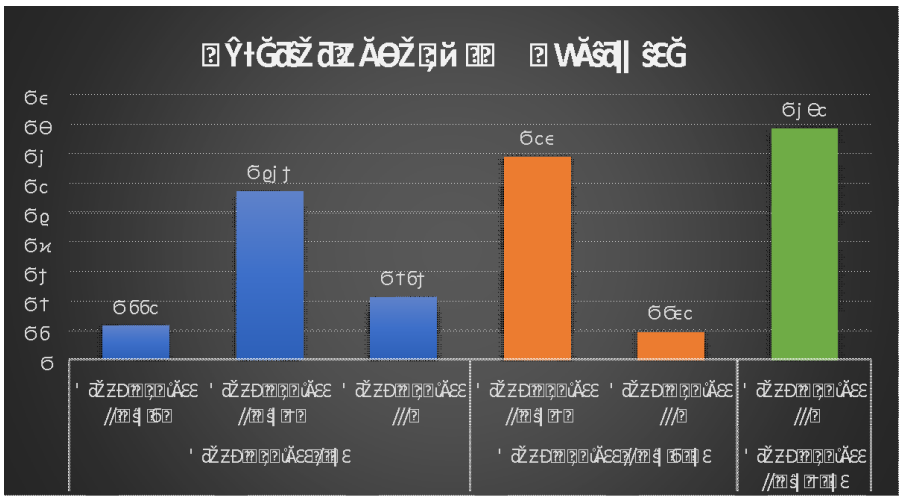
Pairwise comparisons of anterior ratios between the malocclusion groups reveal no significant differences. The mean differences between the groups are minimal, with p-values ranging from 0.465 to 0.998.

These results confirm that there is no statistically significant difference in anterior ratios between any of the compared malocclusion groups.

Table 4: Pairwise comparison between different malocclusion groups in relation to Anterior ratio (%)

Pairwise comparison using Tukey's post hoc test			
Group	**Comparison Group**	**Mean Difference**	**P value, Significance**
Group A (Class I) Vs	**Group B (Class II Division 1)**	**0.116**	**p =0.996**
	Group C (Class II Division 2	**0.573**	**p =0.713**
	Group D (Class III)	**0.213**	**p =0.979**
Group B (Class II Division 1) Vs	**Group C (Class II Division 2)**	**0.690**	**p =0.577**
	Group D (Class III)	**0.096**	**p =0.998**
Group C (Class II Division 2) Vs	**Group D (Class III)**	**0.786**	**p =0.465**

p>0.05 – no statistical significant difference



Graph 4: Pairwise comparison between different malocclusion groups in relation to Anterior ratio (%)

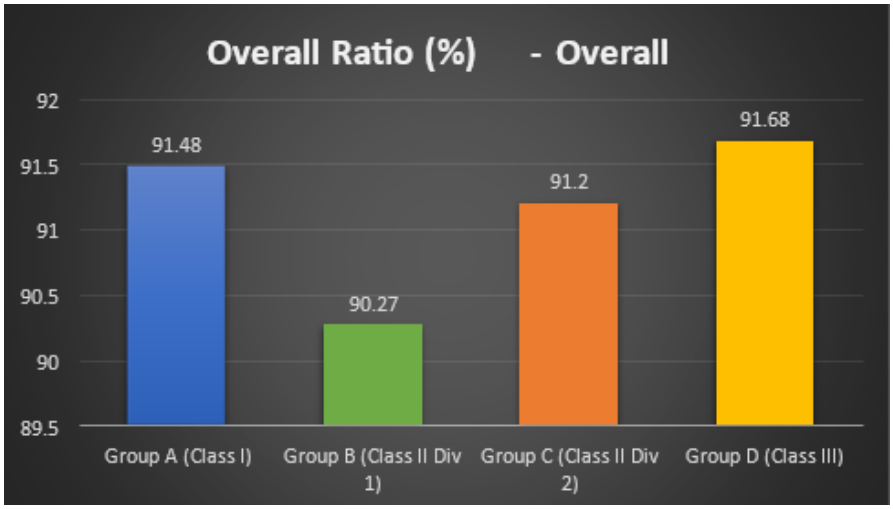
Comparison of Overall Ratio (%) Between Four Malocclusion Groups

The overall ratio comparison among the four malocclusion groups indicates that the mean overall ratios vary slightly, with Group B (Class II Division 1) having the lowest mean (90.27%) and Group D (Class III) the highest (91.68%). The One-way ANOVA F test value is 2.648 with a p-value of 0.049, suggesting a statistically significant difference in overall ratios between the groups.

Table 5: Comparison of Overall ratio (%) between four malocclusion groups using One way Anova F test

Overall Ratio (%)	Mean	SD	One-way Anova F test	P value, Significance
Group A (Class I)	**91.48**	**2.18**		
Group B (Class II Division 1)	**90.27**	**4.27**		
			F = 2.648	**p =0.049***
Group C (Class II Division 2	**91.2**	**2.73**		
Group D (Class III)	**91.68**	**2.19**		

*p<0.05 – Statistical significant difference



Graph 5: Comparison of Overall ratio (%) between four malocclusion groups using One way Anova F test

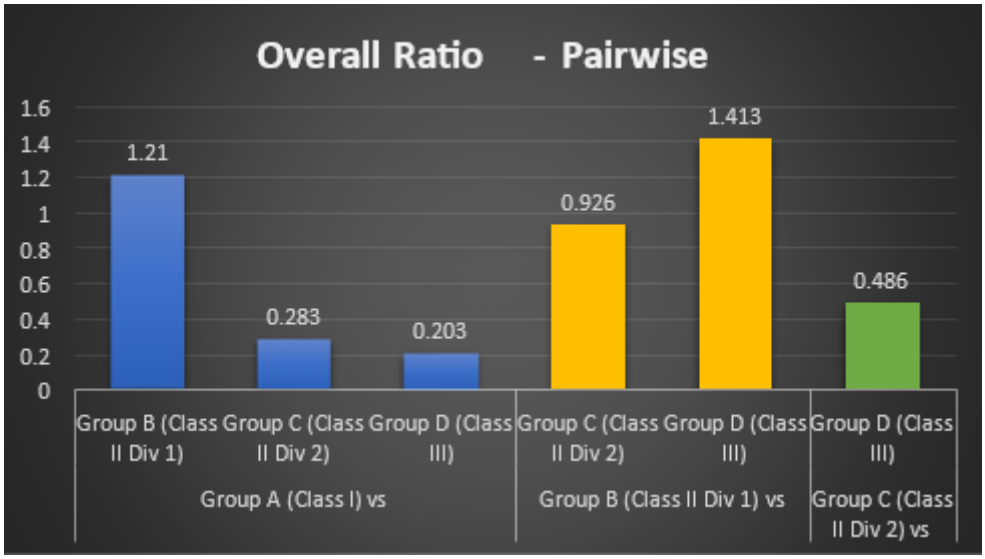
Pairwise Comparison Between Different Malocclusion Groups in Relation to Overall Ratio (%)

Pairwise comparisons of overall ratios show that most comparisons are not statistically significant, except for the comparison between Group B (Class II Division 1) and Group D (Class III), where the p-value is 0.048, indicating a statistically significant difference. This suggests that there is a significant difference in overall ratios specifically between these two groups, while other group comparisons do not show significant differences.

Table 6: Pairwise comparison between different malocclusion groups in relation to Overall ratio (%)

Pairwise comparison using Tukey's post hoc test			
Group	**Comparison Group**	**Mean Difference**	**P value, Significance**
Group A (Class I) Vs	**Group B (Class II Division 1)**	**1.21**	**p =0.118**
	Group C (Class II Division 2	**0.283**	**p =0.954**
	Group D (Class III)	**0.203**	**p =0.982**
Group B (Class II Division 1) Vs	**Group C (Class II Division 2)**	**0.926**	**p =0.322**
	Group D (Class III)	**1.413**	**p =0.048***
Group C (Class II Division 2) Vs	**Group D (Class III)**	**0.486**	**p =0.807**

p>0.05 – no statistical significant difference



Graph 6: Pairwise comparison between different malocclusion groups in relation to Overall ratio (%)

IV. Discussion

The present study aimed to compare the Bolton ratio in normal occlusion and different malocclusion groups within the Navi Mumbai population. The results provide significant insights into the distribution of gender, age, and Bolton ratios across different malocclusion groups, contributing to the understanding of orthodontic variations within this specific population.

The gender distribution across the four malocclusion groups was found to be balanced, with an equal number of males and females in each group. This balanced distribution eliminated potential gender bias, ensuring that the results of the Bolton ratio comparisons were not influenced by gender differences. Previous studies have shown that sexual dimorphism does not significantly affect the Bolton ratio, and the current study supports this finding by demonstrating no statistically significant difference in gender distribution across the groups (Chi-square test value = 0.0, p = 1.000). This consistency aligns with studies by Al-Tamimi and Hashim (2005) and others, which also reported no significant gender differences in tooth size ratios.

The age distribution across the malocclusion groups revealed no statistically significant differences, with mean ages ranging from 21.3 to 22.16 years. This homogeneity in age distribution suggests that age-related factors, such as tooth eruption or wear, did not significantly influence the Bolton ratio in the sample studied. The lack of significant differences in age distribution is crucial, as it ensures that the comparisons of Bolton ratios between malocclusion groups are not confounded by age-related variations. The results are consistent with previous studies, such as those by Lavelle (1972), which suggested that age does not substantially affect Bolton ratios once permanent dentition is fully established.

One of the key objectives of the study was to compare the anterior and overall Bolton ratios between different malocclusion groups. The anterior ratio comparison using One-way ANOVA revealed no statistically significant differences between the malocclusion groups (F = 0.854, p = 0.466). The pairwise comparisons further supported this finding, with no significant differences observed between any of the groups (p-values ranging from 0.465 to 0.998). These results indicate that the anterior Bolton ratio remains relatively consistent across different types of malocclusions, a finding that aligns with previous research by Nie and Lin (1999), who also reported minimal variation in anterior ratios across different malocclusion classes.

In contrast, the overall Bolton ratio did show some variability between the groups. The One-way ANOVA results indicated a statistically significant difference in overall ratios (F = 2.648, p = 0.049), particularly between Group B (Class II Division 1) and Group D (Class III), as highlighted by the pairwise comparison (p = 0.048). This finding suggests that while the anterior ratio may be stable, the overall ratio can vary depending on the type of malocclusion, especially between certain groups. The higher overall ratio in Class III malocclusion could be indicative of a greater discrepancy between the mesiodistal widths of the maxillary and mandibular teeth, which could contribute to the characteristic occlusal relationships observed in Class III cases. This observation is supported by studies such as those by Fattahi et al. (2006), who also found significant differences in overall ratios among different malocclusion types, particularly in Class III malocclusion.

The findings of this study have important implications for orthodontic treatment planning, particularly in the Navi Mumbai population. The lack of significant differences in the anterior ratio across malocclusion groups suggests that orthodontic treatment plans can generally rely on consistent anterior tooth size relationships, regardless of the type of malocclusion. However, the significant differences in the overall ratio,

especially between Class II Division 1 and Class III malocclusions, highlight the need for careful consideration of tooth size discrepancies when planning treatment for these specific cases. Orthodontists should be aware of these potential discrepancies and may need to incorporate tooth size analysis more rigorously into their diagnostic and treatment planning processes to achieve optimal occlusal outcomes.

The study also underscores the importance of population-specific data in orthodontics. While Bolton's original ratios are widely used, this study suggests that these ratios may not be universally applicable, particularly in populations with diverse ethnic and genetic backgrounds, such as those in Navi Mumbai. The differences observed in this study emphasize the need for orthodontists to consider local population data when applying Bolton's ratios, as reliance on data from other populations could lead to suboptimal treatment outcomes. This finding is consistent with the work of Rahman et al. (2023), who also advocated for population-specific Bolton ratios in their study of Malaysian orthodontic patients.

The results of this study contribute to the growing body of literature on the application of Bolton ratios in different populations. While previous studies have reported varying degrees of discrepancy in Bolton ratios across different ethnic and malocclusion groups, the current study adds valuable data from the Navi Mumbai population, which has not been extensively studied in this context. The findings align with those of other studies that have found significant differences in overall ratios between malocclusion types but minimal differences in anterior ratios. For example, the study by Uysal et al. (2005) on Turkish populations also reported significant differences in overall ratios among malocclusion groups, particularly in Class III cases, while anterior ratios remained relatively stable.

Moreover, the study's findings are consistent with the broader literature that highlights the importance of considering tooth size discrepancies in orthodontic treatment. The results support the continued use of Bolton's analysis as a diagnostic tool while also suggesting that orthodontists should be mindful of the potential limitations of using a one-size-fits-all approach to tooth size analysis. This nuanced understanding is crucial for achieving optimal treatment outcomes, particularly in populations with diverse dental and facial characteristics.

Despite its contributions, the study has some limitations that should be acknowledged. First, the sample size, while sufficient for detecting significant differences in overall ratios, may still be limited in its ability to generalize the findings to the broader Navi Mumbai population or other similar populations. Future studies could benefit from larger sample sizes and the inclusion of more diverse subgroups to enhance the generalizability of the results.

Additionally, the study relied on pre-treatment dental casts for measurement, which, while standard in orthodontic research, may introduce some measurement errors, particularly in cases with severe malocclusions where tooth positioning can be more variable. Although digital vernier calipers were used to minimize these errors, future studies could explore the use of more advanced imaging technologies, such as 3D scanning, to enhance measurement accuracy.

Furthermore, the study focused exclusively on mesiodistal tooth size discrepancies as measured by Bolton ratios. While these are important factors in orthodontic diagnosis and treatment planning, they do not capture the full complexity of occlusal relationships or the functional aspects of occlusion. Future research could explore the integration of Bolton ratios with other diagnostic tools, such as cephalometric analysis or functional occlusal assessments, to provide a more comprehensive understanding of the factors contributing to malocclusion.

Finally, while this study provides valuable data on the Navi Mumbai population, it is important to recognize that orthodontic practice increasingly involves the treatment of patients from diverse backgrounds. Future research should continue to explore the applicability of Bolton ratios across different populations and consider the potential influence of factors such as diet, cultural practices, and environmental conditions on tooth size and occlusion. This broader perspective will be essential for developing more tailored and effective orthodontic treatments that meet the needs of a global patient population.

V. Conclusion

The study concluded that while the anterior Bolton ratio remains consistent across different malocclusion groups in the Navi Mumbai population, the overall Bolton ratio shows significant variability, particularly between Class II Division 1 and Class III malocclusions. This indicates that orthodontists should carefully consider overall tooth size discrepancies when planning treatment, especially in cases involving Class II Division 1 and Class III malocclusions. The findings also suggest that Bolton's original ratios may not universally apply to all populations, emphasizing the need for population-specific data in orthodontic diagnostics and treatment planning. Overall, the study reinforces the importance of tailored orthodontic approaches to achieve optimal treatment outcomes.

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